

Studies on Filtration of Fermentation Wastewater Using Sand-Carbon Filter

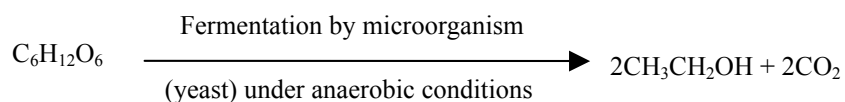
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Abstract

Biofuels production from cellulosic materials as carbohydrate source is being investigated as one of the alternatives to the solution of the energy problem. One of the potential processes involves simultaneous hydrolysis and fermentation. The wastewater from such process must be treated before being released to the environment. In order to make the process even more economical and environmentally friendly, the wastewater needs to be treated and recycled. This study is investigating the use of rapid sand -carbon filter in the reduction of organic materials and salt in the wastewater from a fermentation process. The filtration rate, conductivity and absorbance were monitored as wastewater was run through the system. The rate of filtration dropped as more wastewater was filtered. This suggests that clogging was taking place in the system as more wastewater was filtered. The absorbance at 570nm and 280nm of the filtrate decreased which suggests that the system was able to filter the wastewater and achieve a significant treatment level. Different filter setups and filter media will be studied in order to improve the filtration efficiency and filtrate quality.

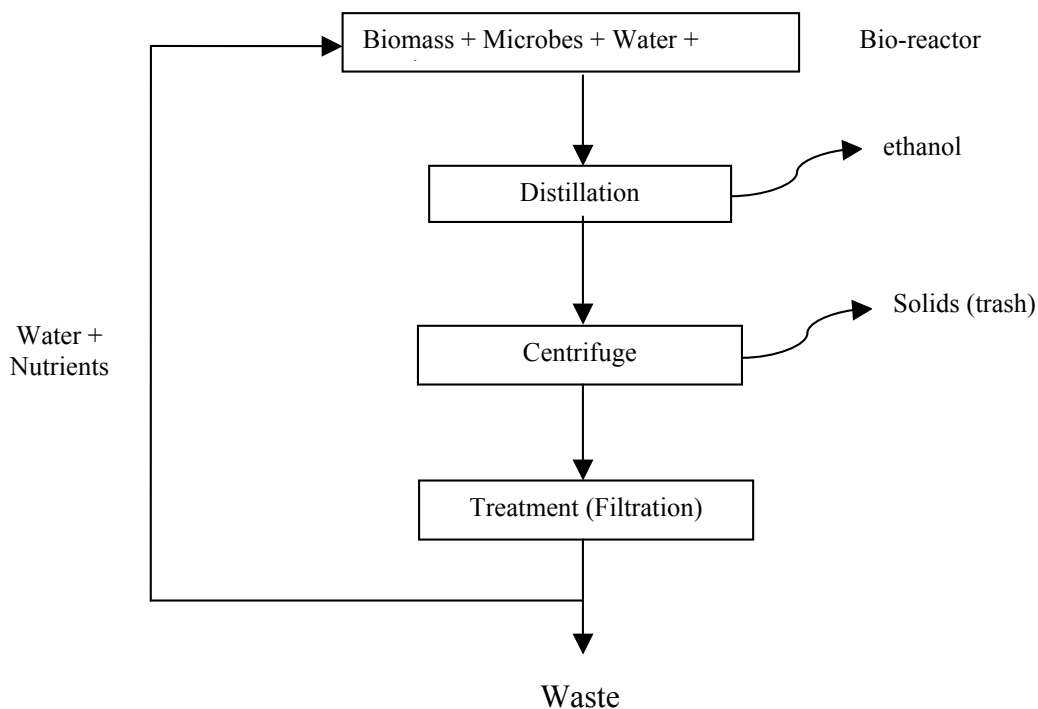
Introduction

With oil and gas prices fluctuating, there is a need to reduce the dependence on fossil fuels. Environmental issues related to fossil fuels also add another dimension to the problem and hence alternative sources to these fuels are being explored. One of the alternative sources coming up is ethanol. Ethanol is produced by microbial fermentation of sugar. Two major components of plants, starch and cellulose, are both made up of sugars, and can in principle be converted to sugars for fermentation. Currently, only the sugar (e.g. sugar cane) and starch (e.g. corn) portions can be economically converted.



In order to produce adequate ethanol to meet the fuel needs, much corn will be needed and this will tend to hurt food and feed supply and prices. Therefore the need for research into alternative carbohydrate sources. A microorganism has been discovered from Chesapeake Bay that is capable of metabolizing almost a variety of organic material. This microbe *S. degradan* is being investigated to degrade biomass in a bio-reactor to produce ethanol by a start-up company on the University of Maryland College Park campus, Zymetis Inc. Various biomass including newsprint, agriculture byproducts such as corn stover are being studied as feed in a bioreactor with nutrients in form of salts for their growth. The products of the process are sugars, ethanol, metabolites, water and nutrients. Ethanol is separated through distillation and degraded solids (trash) through centrifuge. The remaining solution contains water, dissolved organics (proteins, sugars), salts (nutrients) and small amount of suspended solids (trash). In order to make the process of ethanol production even more economical and environmentally friendly, the wastewater needs to be treated recycled.

The diagram below is a chart flow showing the processes involved in ethanol production and recycle of water in the process:



The objective of this study is to investigate the use of a sand filter in treating the wastewater (fermentation effluent) in order to recycle the water to the process. In other words, the system should be able to remove a significant amount of dissolved organics (proteins) so that the filtrate contains only salts (nutrients).

Background

Sand Filters

Sand filters are generally easy to design and construct and also easy to maintain. Most energy is only required in cleaning (backwashing) process.

Slow sand filters have the capability to achieve a certain level of organic removal but have limitations in their design and operation:

- Due to the low loading rates, significantly large areas for filtration are required
- The biofilm formed on top of the filter, poses an environmental challenge when it comes to disposal
- Slow sand filters need to be enclosed during winter to maintain conducive temperatures and also need to be covered during sunny seasons to avoid excessive growth of the biofilm.

Rapid sand filters prove superior over slow sand filters in that:

- they can treat more capacity at a time
- they have no weather or season restrictions

They however cannot remove dissolved organics since their mode of treatment is primarily physical. Incorporating activated carbon in the system makes removal of some degree of organics and odor possible. Such a system may achieve the kind of treatment level required to recycle the wastewater from ethanol production.

Sand as a filter medium is characterized by the particle size and uniformity coefficient which influence the porosity and hence filtration rate through the filter. Particle size and uniformity coefficient are both established through a sieve analysis process. The particle size is the effective size (ES) which is defined by the size of screen opening where 90 % of a sample of granular

media is retained on the screen and 10 % passes through the screen, and is referred to as D_{10} . The larger the grain size, the faster the wastewater moves through the sand and the more wastewater that can be filtered. However, if the grain size is too large, treatment efficiency will be reduced due to short retention times.

Uniformity coefficient (U_c) is a numeric estimate of how sand is graded and is dimensionless. Sand with all the particles in two size ranges would have a low U_c while sand with near equal proportions in all the fractions would have a high U_c value. The U_c is calculated by dividing D_{60} (the size of screen opening where 60% of a sample passes and 40% is retained) by D_{10} . The idea is that the sand grains should be about the same size i.e. relatively uniform. A uniformity coefficient of 1.5 or less is recommended, the intention being to avoid clogging at higher loading rates. If the grain sizes vary greatly, the smaller ones will fill the spaces between the larger particles and clogging will easily occur.

The important features of construction and operation of a rapid sand filter⁷ are shown in the table below:

Feature	Measure
Sand size (effective size)	0.45mm
Uniformity coefficient	1.5 and lower
Rate of filtration	100 to 475m ³ /m ² /d (2500-11650 gal/ft ² /d)
Depth of filter bed	0.75m sand and 0.5m gravel
No. of filter units	At least 2
Length of run	12 to 72 hours

The filter area required for sand filters is determined by the hydraulic loading rate. Using the typical loading rates provided in literature, the filter area will be given by;

$A = Q/L$ where A is the required filter area, Q is the wastewater flow and L the hydraulic loading rate

Sand or other filter media available may not meet ES and uniformity coefficient specifications.

In this case, the available sand or other filter media is tailored to requirements in a process where

unacceptable particle sizes (too fine and too coarse) are removed through sieving and passing water in an upflow direction.

Activated Carbon

Activated carbon is produced by burning carbon rich materials such as coal, wood or nut shells. . It is either steam or chemically activated to further develop its internal pore structure. The idea is to make it make it extremely porous and thus to have a very large surface area available for adsorption or chemical reactions. There are two principal mechanisms by which activated carbon removes contaminants from water; adsorption, and catalytic reduction, a process involving the attraction of negatively-charged contaminant ions to the positively-charged activated carbon. Organic compounds are removed by adsorption. Activated carbon filters require very little maintenance, however, it is very important to ensure that filter replacement schedules are followed to ensure proper filtration at all times. The two most important factors affecting the efficiency of activated carbon filtration are the amount of activated carbon in a unit and the amount of time the contaminant spends in contact with it. The more carbon there is, the better the efficiency. Particle size also affects contaminant removal rates.

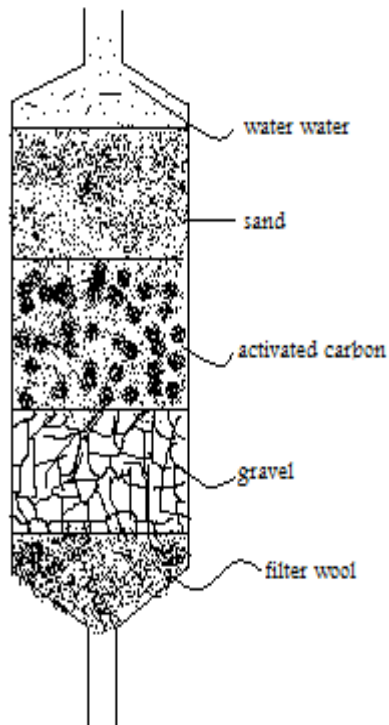
The effectiveness of activated carbon is measured by the adsorbing ability offered by the degree of microporosity. The size of a granular activated carbon system is based on the contact time, hydraulic loading rate, carbon depth and number of units. Some typical design values⁷ are as follows;

Contact time	2-10 min
Hydraulic loading rate	8-10m/h
Carbon depth	2-3m
No. of contactors	≥2 in parallel

Materials and Methods

The activated carbon, Sand – quartz (0.6-1.2mm size), Pea gravel (5mm size) and filter wool were all commercial grade obtained from a local pet store. Absorbance was measured with a Spectronic Genesys 5 spectrometer and conductivity was measured with Accumet AR 20 pH/conductivity meter.

Filter wool, gravel, activated carbon and sand were packed in a column as shown below:



The column contained 80mm sand, 60mm activated carbon and 50mm gravel

These measurements were derived from typical design values for sand and activated carbon beds⁷. The filtration area was 2826mm². Wastewater was run through the column in 300ml portions. A constant head of 20mm was maintained above the sand. The filtration rate was estimated by collecting known volume at 5minute interval.

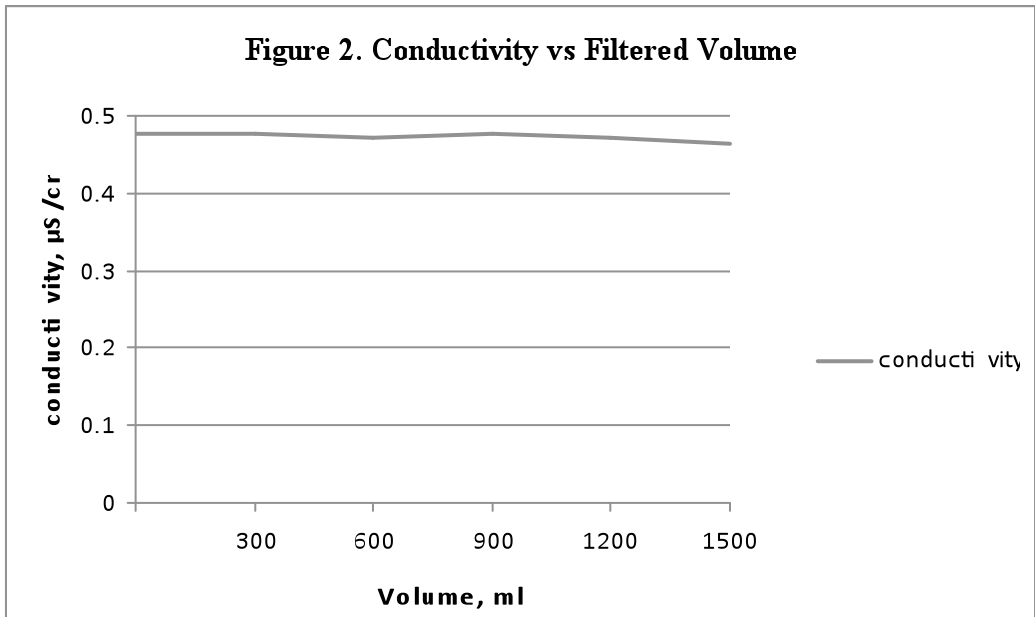
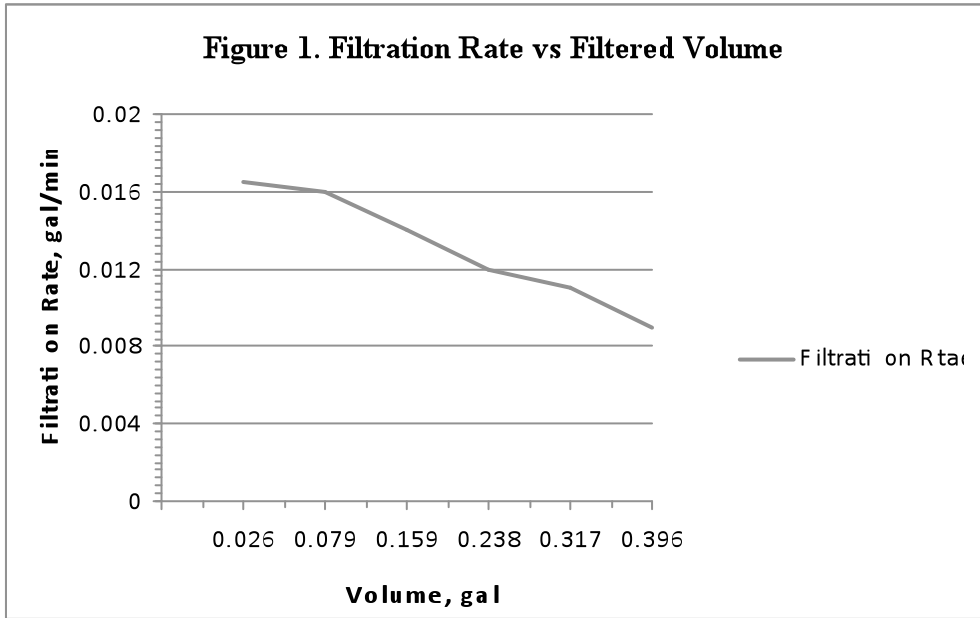
The spectrometer was zeroed with distilled water and the absorbance for each of the filtrate collected for each run was measured, at 570nm and 280nm wavelength. The absorbance of the original wastewater was also measured.

The conductivity for the filtrates and wastewater was measured using KCl as the standard

Results

Figure 1 shows the change in filtration rate with the number of runs. The filtration rate decreased from 0.016 GPM to 0.009 GPM over five runs. The conductivity remained varied from 0.478 - 0.464 μ S/cm during the five runs (Figure 2). The absorbance of the filtrate was measured at 570

nm to indicate the clarity of the filtrate. The absorbance changed from 0.052 to 0.008 (Figure 3). The absorbance had decreased by 80% after a filtration volume of 600mL. The removal of organic material such as protein was followed by measuring the Absorbance at 280nm. The absorbance at 280nm decreased from 3.48 to 2.96 as shown in figure 4.



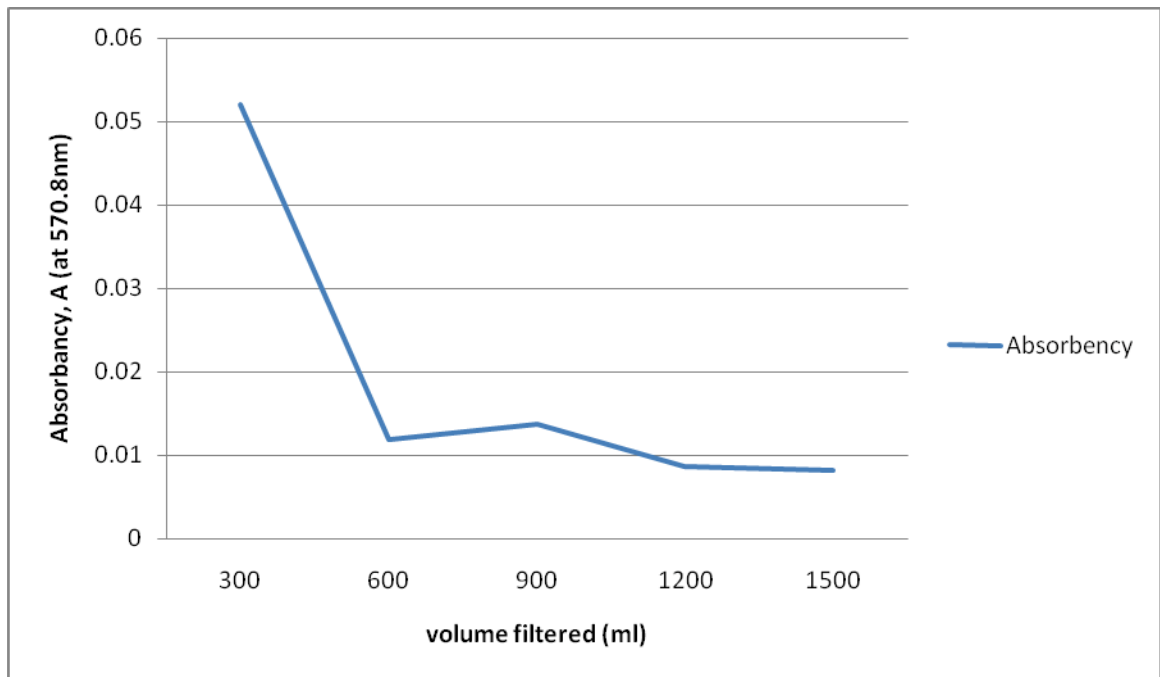


Figure 3. Absorbance at 570.8nm vs filtrate volume

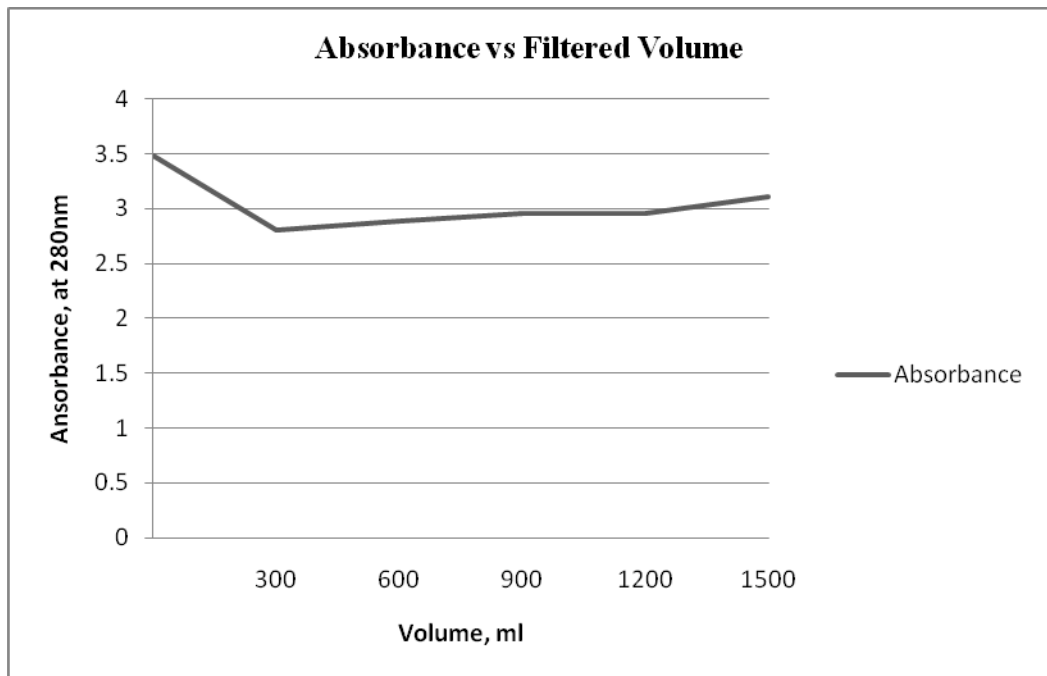


Figure 4. Absorbance at 280nm vs filtration volume.

Discussion

By visual observation, the filtrate collected was clearer than the wastewater. The odor had also been greatly reduced to unobjectionable levels. The filtration rate tends to decrease as more wastewater goes through the filter media. This is an indication of clogging taking place as more solids are trapped within the sand and therefore backwashing is required at the point when rate is too low. Conductivity does not show significant difference as filtration progresses. Conductivity is a measure of ionic compounds dissolved in water. In view of this, the interpretation is that the filtrate contains almost the same amount of dissolved salts as the original wastewater.

The absorbance of the filtrate from each run and for the wastewater shows a significant difference. Absorbance at 280nm measures the concentration of protein in a solution. Proteins in solution absorb ultraviolet light with absorbance maxima at 280 and 200 nm. Amino acids with aromatic rings are the primary reason for the absorbance peak at 280 nm. Peptide bonds are primarily responsible for the peak at 200 nm. As filtration began, the filtrates' absorbance displayed a significant decrease from the wastewater's absorbance. As filtration progressed, the absorbance gradually increased but even after filtering 1500ml, it was still below the measure of the wastewater.

Conclusion

From analysis of the results, the system displays a significant achievement of treatment. More wastewater should be run through the system to establish the point at which backwashing is necessary. The point of exhaustion of the activated carbon will also be established when the absorbance of the filtrate is or nears the absorbance of the wastewater. At this point, replacement or regeneration of activated carbon is necessary. In practice, activated carbon is incorporated in a separate unit from the sand but follow the same sequence as the setup. This is in order to allow for replacement of activated carbon when it gets exhausted. Another reason is that backwashing does not work well with activated carbon. The backwashing process mixes the activated carbon during which compounds adsorbed located at the top may end up lower into the media where desorption is likely to occur. To improve the efficiency of the systems, different setups in terms of depth, sizes of the filter media, configurations and setups should be explored. A recent study

in China¹⁰ found that two carbon adsorbers in series mode of operation often constitute the most cost effective treatment process. The lead adsorber allows a high utilization of carbon's adsorptive capacity, whereas the polish adsorber ensures excellent treatment performance. Alternative filter materials such as anthracite and lightweight aggregate to substitute sand and activated carbon respectively should also be experimented. Materials used in the filter should be easy to acquire and relatively cheap. Gravel for example, may be substituted by pumice such as broken glass. In another recent study in China⁹, corn cob was impregnated with phosphoric acid (H₃PO₄) used to produce activated carbon.

The practicability of any filter system will be determined by its efficiency in terms of treatment capability (quality and quantity), environmental and economic friendliness (cost of maintenance).

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